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Improving complex governance schemes around Western Baltic Herring, through the development of a Long-Term Management Plan in an iterative process between stakeholders and scientists.

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Abstract

Despite its relatively small stock size and economic value, Western Baltic spring spawning herring (WBSS) is managed in a highly complex governance scheme, with demanding scientific challenges and an elaborate political process of resource allocation among fishing fleets. WBSS herring spawns in the western Baltic Sea, where it is exploited by several EU fishing fleets. It migrates into the Kattegat, Skagerrak and eastern North Sea areas, where it mixes with North Sea autumn spawning herring (NSAS), in an age and season-dependent pattern with high variability, and where it is exploited by both EU and non-EU fleets. For the two separate management areas, TACs are set at different times in the yearly TAC-setting process, and this can result in conflicts over quota allocations to individual fleets.

Industry stakeholders of two Regional Advisory Councils – the Pelagic and Baltic Sea RACs – and scientists involved in the FP7 JAKFISH project engaged in collaboration, aiming to improve stock management through joint development of a robust Long-Term Management Plan. A common understanding of relevant scientific and political issues was developed and used to conduct Management Strategies Evaluations in an interactive process.

In this paper we review the project’s achievements, and analyze the effectiveness of the collaborative process itself, and how it affected individual endeavours of the scientific and the stakeholder groups. Finally, we reflect upon the concept of Results-Based Management and how such science-stakeholder collaborations could play a role in a RBM system.

1 INTRODUCTION

1.1 Background of issues

1.1.1 Natural issues around stock mixing

Atlantic herring displays large variations in migration and homing behaviour, and genetic studies have identified population structure across both small and large geographic scales (e.g., Bekkevold et al., 2005, 2007; Mariani et al. 2005). In ICES subdivisions 20 (Skagerrak, area IIIaN), 21 (Kattegat, ICES area IIIaS) and 22-24 (Western Baltic) a number of herring sub-populations spawning in winter, spring or autumn occur sympatrically and are exploited in a mixture by the fishery. These sub-populations are gathered into stock units for assessment and management purposes. Although the relatively high spatio-temporal overlap of stocks may bear a high potential for gene flow, it has been shown that herring spawning components maintain significant reproductive isolation, possibly affected by selective differences among spawning and/or larval habitats. Knowledge of stock integrity is of unequivocal importance for sustainable fisheries management, since variable compositions in mixed areas, together with asynchronous population dynamics, may lead to over-fishing of individual stock components if not all components are managed to ensure (or achieve) sustainable exploitation.

Schematically, the main patterns can be summarised as follows: the western Baltic spring spawning (WBSS) herring spawns in the Western Baltic Sea. It migrates annually towards the Kattegat, Skagerrak and up to the eastern North Sea, in an age- and season-dependent pattern with high variability (Ulrich et al., in prep.). There, it mixes with North Sea autumn spawning herring (NSAS), whose stock distribution also extends into the area IIIa (Figure 1).

To ensure conservation of the major herring stocks present in IIIa and adjacent areas, this variable mixing must be addressed in the advice on the fishery. The combination of the possibility for stock and lifestage selectivity in the fishery and the natural variation in migration patterns in the major stocks necessitates knowledge of the interaction between these dynamic processes in order to optimise the herring fishery in the area - in terms of stock preservation, economical aspects and the ecology of the system.

1.1.2 Political issues around resources allocation

Despite its relatively small stock size and economic value, western Baltic spring spawning herring (WBSS) is managed in a highly complex governance scheme. A number of distinct fleets exploit the WBSS herring in its various stages and areas. Around the spawning area in western Baltic, it is exploited by the various pelagic fleets from Denmark, Sweden, Germany and Poland. This component is gathered under the single group “Fleet F” by the ICES Herring Assessment Working Group (HAWG, ICES 2009). Members of these fleets are represented in the Baltic Sea Regional Advisory Council (BSRAC). In Kattegat and Skagerrak the mixture of WBSS and NSAS stocks is exploited by various pelagic fleets from Denmark, Sweden and Norway, either targeting large herring for human consumption (“Fleet C”) or catching small herring as by-catches of the industrial fishing fleet targeting mostly sprat and sandeel for fishmeal reduction (“Fleet D”).

The fishery for human consumption in the North Sea is referred to as “Fleet A.” It targets primarily NSAS herring, but simultaneously catches substantial quantities of WBSS adults in the eastern part of area IVa The fleets C, D and A are represented in the Pelagic Regional Advisory Council (PelRAC).

PelRAC has long been widely involved in developing LTMP in collaboration with scientists and managers (see e.g. review in ICES SGMAS 2008), whereas this is much newer in the history of BSRAC, in particular for the pelagic fisheries. There is only limited overlap in membership between both RACs, and historically there has been almost no collaboration in advising on WBSS herring management.

ICES HAWG (2009) annually follows complicated procedures encapsulating this complexity, in order to provide consistent TAC advice. The final TAC for WBSS is shared between the area 22-24 and the area IIIa. Although the sharing should theoretically follow an equal 50-50% split between both areas, this value is not an official agreement and is therefore renegotiated each year. Incidentally, the rule is diverted from, as happened in 2009. When deciding upon a TAC for area 22-24 in October 2009, the European Council decided that most of the reduction in catches of the WBSS stock as advised by ICES should be realised in area IIIa. However, negotiations between the EU and Norway in November 2009 on the TAC to be set for area IIIa did not follow this approach and a TAC for area IIIa was agreed upon, resulting in an overall fishing mortality to the WBSS stock much higher than what would have been in line with the ICES advice.

This example illustrates well the complexity of the governance system in which this stock is managed and how it might jeopardise the sustainability of the fishery. It also points to the potential for simplifying and rationalising the situation by developing a long-term management plan which should provide predictability and stability to all parties if adhered to.

1.1.3 Scientific issues around uncertainty

Historically, the stock assessment annually performed by ICES HAWG has been considered of poor quality. It has however greatly improved since 2008 and is now considered accurate (without bias), but with low precision as the confidence intervals around the final estimates are large (ICES HAWG, 2009). This occurs in spite of relatively large scientific resources dedicated to this stock compared to its commercial importance. The main reason lies in the complex dynamic of the stock, which cannot be easily captured through standard catch-at-age analyses (Ulrich et al., in prep.). Catches from scientific surveys and commercial landings are split into NSAS and WBSS components based on regular scientific samples, which however cover the whole fishing area unequally. A number of splitting methods of variable precision exist, including meristic characteristics (vertebrae counts), otolith microstructure analysis or, more recently, a combination of otolith microstructure and otolith shape analysis (Clausen et al., 2007). Several time-series surveys are available to tune the stock, although their spatio-temporal coverage is not always fully appropriate and their inter-annual variability can be large (Payne et al., 2009a). The time series are short as the data is considered too poor prior to 1991, and better recruitment indicators are called for. There is no clearly defined spawning stock - recruitment relationship, which implies that the definition of reference points is incomplete.

Thus, in spite of the assessment being scientifically consistent, large discrepancies may occur between its outcome and perception by the fishermen.

1.2 The JAKFISH project

Over the last decade or two, there has been an increasing amount of literature dedicated to uncertainty in science for policy. Concepts and tools have been developed in order to discuss and solve problems related to what is perceived as a limited focus on uncertainty. For example, there have been discussions on mismatch experienced between certain policy problems and the scientific tools to solve them, and on a lack of transparency in the soundness of scientific results (Funtowicz and Ravetz 1990; 1993; Wynne 1992; Walker et al. 2003; van der Sluijs et al 2003). As these topics are closely related to the relevance and usefulness of scientific input to policy, stakeholder participation has been regarded as crucial (Funtowicz and Ravetz 1993; Wynne 1992; Renn 2008; Funtowicz and Strand 2007). The call for an ecosystem approach to fisheries or to results based management can be seen as examples of concern about the relevance of existing advisory frameworks, and limitations on how uncertainty is dealt with and accounted for have been discussed in the academic literature (Hilborn et al. 2001; Degnbol and McCay 2006; Reeves and Pastoors 2007; Nielsen and Holm 2007; Patterson and Résimont 2007; Sparholt et al. 2007; Hauge et al. 2007).

The EU FP7 research project JAKFISH[1] (Judgement and Knowledge in Fisheries Involving Stakeholders, 2008-2011) has aimed at addressing these questions, and in particular at "*investigating the roles that scientists play to help formulating policies, and how* ***governance approaches*** *can be developed which enable* ***policy decisions*** *to address* ***uncertainty and complexity*** *based on research and with the* ***participation of stakeholders.***" This research is articulated around a number of case-studies involving participatory modelling with stakeholders around management issues (Figure 2). The management of WBSS herring was thus chosen as a relevant case study.

2 DEVELOPMENT OF LTMP PROPOSAL

2.1 Defining objectives

2.1.1 Initial objectives

A number of preliminary discussions and small informal meetings between some Danish members of the PelRAC and scientists initially took place in 2008 and 2009, largely in the frame of the previous Project GAP1 (Mackinson and Neville, 2009). Key aspects of the scientific and institutional issues were presented and discussed, and the basis of the work to be developed was defined. The stock mixing between NSAS and WBSS herring and the variability of the selectivity of the fleets and their spatial patterns were the main scientific issues to be focused on in the intended model, consistently with some complex approaches developed for the herring stocks in the west of the British Isles (ICES SGHERWAY, 2009).

Beside, the discussions focused on the agreed necessity to extend the stakeholders involvement to other major interest groups, and BSRAC in particular, into the process.

2.1.2 Broader involvement in EC policy issues

Over the same period of time, the EU initiated in late 2008 a process aiming at establishing long-term management plans for all pelagic stocks in the Baltic Sea, including WBSS herring. The process involved first a request to ICES for proposing robust values of long-term management objectives in terms of fishing

[1] https://www.surfgroepen.nl/sites/jakfish/default.aspx

mortality (A), with a maximum inter-annual variation of the TAC (B) and a trigger spawning stock biomass (C). ICES met in February 2009 (ICES WKMAMPEL) and proposed the values displayed in Table 1.

This analysis of biological stock-based simulations was followed by a socio-economic impact analysis performed by MRAG over spring and summer 2009, and acknowledged by STECF Both analyses were used by the EU to formulate in late March 2010 a Commission Non-Paper on the establishment of a multi-annual plan for the pelagic stocks in the Baltic. This EU initiative acted as another decisive driver to sustain the full involvement of all stakeholders in spring 2009, and the BSRAC in particular, to agree on a LTMP for WBSS. But meanwhile, it removed the immediate need to develop an advanced bio-socio-economic Management Strategy Evaluation (MSE) model to perform similar impact assessment analyses. On the contrary, it focused the RACs and the JAKFISH scientists on the consideration of whether the outcomes of ICES WKMAMPEL (2009) were the most appropriate ones, or whether alternative Harvest Control Rules (HCR) would be preferable. Of key importance here was the trigger biomass (C), considered undefined by ICES WKMAMPEL (2009). The immediate consequence of this is that, according to the HCR suggested in Table 1, the fishery should be closed as soon as the SSB of WBSS herring is estimated by ICES to be below 110 000 t. It is likely that this HCR may not be adhered to by industry stakeholders, especially given the difficulty of establish ing true limit reference points for this stock (ICES HAWG, 2009).

Therefore, the group made its priority to agree first on the (A), (B) and (C) terms of the future LTMP for WBSS, before addressing additional issues such as the impact of the mixing of WBSS with NSAS. Finally, the implementation in spring 2010 of a new MSY framework in the ICES advice, with the subsequent need to suggest new single-stock reference points F_{MSY} and $B_{MSYtrigger}$ provided a basis for the group to focus on long term TAC setting principles.

2.1.3 Final objectives achieved

As a consequence, the scientific objectives shifted from developing a new innovative integrated modelling framework into evaluating and communicating the risks and sources of uncertainty linked to the approach put forward by the EU initiative. An iterative participatory modelling process involving both RACs and the JAKFISH scientists developed between May 2009 and May 2010, aiming at:

- Getting a common understanding of the process and the implications of simulations-based Management Strategies Evaluation on a single-stock basis,
- Evaluating in collaboration a number of alternative management scenarios,
- Reaching agreement and commitment on a preferred Harvest Control Rule.

2.2 Iterative process around simulation setup

Milestones in the process were the four meetings (besides the initial informal meetings during the earliest period), which took place over the period.

The first meeting (May 2009) was sustained by an EU suggestion to create a common Focus Group involving both RACs around the potential multi-annual management plan for pelagic stocks in the Baltic, and served as an introductory meeting for the various actors.

The second meeting (October 2009) was attended by a smaller group of stakeholders, all heavily involved in WBSS herring fisheries. The meeting focused on the scientists explaining the outcomes of ICES WKMAMPEL (2009) and its recommendations to the EC in terms of values for (A), (B) and (C) in the HCR, and communicating the scientific assumptions behind them. Differences in perception between fishermen and scientists were identified and discussed, and there was also a very preliminary discussion on a possible set of objectives for a LTMP.

The third meeting (January 2010), although attended by a very large number of more diverse stakeholders, was mainly driven by the scientists, in an attempt to explain in further detail the issues discussed during the second meeting. The scientific process leading to the current perception in stock assessment was reviewed, and its intrinsic variability was underlined. This was meant in the aims of both i) reaching understanding from the stakeholders about the precarious state of the stock and commitment around the urgent need to establish a rebuilding strategy, and ii) justifying why a LTMP for WBSS herring should be particularly cautious and robust to the main sources of uncertainty. After having addressed the theoretical and scientific background, a first set of simulation results for different HCRs was presented, and this gave a general overview of the effects of and trade-offs between different objectives, i.e. ecological versus more economically oriented ones. The second and third meetings were recorded on tape for further analysis.

The fourth meeting (March 2010) was driven by the stakeholders. More simulation results were presented by the scientists, after which a discussion was held mostly among the stakeholders from both RACs on the simulation results as well as on political arrangements to be included in the LTMP. The process ended in May 2010, when both RACs and the scientists independently formulated their contributions and recommendations in response to the Commission's non-paper on the establishment of a multi-annual plan for the pelagic stocks in the Baltic.

Beside these meetings, the work progress was framed by regular email correspondence between stakeholders (mostly PelRAC) and scientists regarding requirements about the types of scenarios to be analysed and the evaluation criteria of interest (Table 2), as well as timely feedback on the ongoing results. As such, the process has co-evolved until reaching the final set-up and results which formed the basis for the final recommendations.

2.3 Modelling frame

The MSE model developed for WBSS herring used a standard full-feedback approach following the most recent state-of-the-art guidelines from e.g. ICES SGMAS (2008) and ICES WKOMSE (2009), and programmed in the R environment (R core Team, 2008) using the FLR framework (Kell et al., 2007). The model was conditioned on the ICES HAWG (2009) assessment results and final runs included 1,000 stochastic simulations. The choice and parametrisation of specific sources of variability and uncertainty included in the projections reflected largely the main issues acknowledged by the scientists or discussed between stakeholders and scientists (see chapter 3), and in particular:

- There is no evidence of the existence of a stock-recruitment relationship; however since 2002 the recruitment has consistently been well below the long-term average. Payne et al. (2009) have demonstrated that climate change and increased water temperature could negatively affect North Sea herring recruitment, and the same could potentially occur for WBSS. Therefore, a Hockey-Stick

SRR was chosen with average recruitment at the recent (2003-2007) geometric mean of assessment estimates and break point at the lowest observed SSB (112 000t). On the other hand, recruitment was a main source of disagreement between stakeholders and scientists, and the recently estimated recruitment failure did not seem to be supported by fishermen's observations. This discrepancy could not be resolved, but potentially large year-classes were allowed to occur in the simulations through a high random deviation in the SRR (CV calculated on the full time-series =0.53);

- As mentioned above, the assessment is estimated to be accurate but imprecise, and the confidence interval is large. In addition, the FLICA model used by ICES HAWG cannot be easily included in large-scale stochastic simulations. Using a standard alternative stock-assessment module like FLXSA, as done by Kell et al. (2009), would not adequately reflect the actual uncertainty experienced by the stakeholders. Therefore, some technical effort was dedicated into properly extracting and propagating the most recent assessment uncertainty using the variance-covariance estimates from ICES HAWG (2009) into the projections. These uncertainty estimates are particularly large for recruitment age, thus reflecting again the potential discrepancies.

- Although the mixing between NSAS and WBSS has not been fully modelled yet (Ulrich et al., in prep.), the empirical knowledge on the stock dynamics, as well as the preliminary analyses of historical scientific data, suggest the existence of some seasonal patterns by area with a degree of inter-annual variability in the IIIa. This variability implies that the TAC in place in area IIIa can potentially include either a smaller or a larger proportion of WBSS herring than assumed in the short-term forecast based on assessment results. This is not the case in the Western Baltic were no mixing with NSAS is assumed to occur. As an initial rough guess we therefore included a 25% uniform deviation on the implementation of the IIIa share of the WBSS TAC, but this figure may be an underestimation of the actual mixing. In accordance with a joint request from both RACs the TAC share was consistently split at 50-50% between both areas .

2.4 Final results

Examples of some of the HCRs tested are displayed in Figure 3, and final summary results are given tables 3 and 4. A number of synthetic figures showing up time series (Figures 4 and 5) and trade-offs between key output variables were discussed (Figure 6). The figures focused on the risk levels, i.e. the 5% worst-case results in terms of both risks to the biomass and foregone yield.

A comparison (Table 5) between the HCR suggested in the Non-Paper (Target F= 0.25, and F=0 if SSB<110kT, Scenario A) and the preferred HCR suggested during the JAKFISH collaborative process (Target F=0.25, and sloped F if SSB<110kT, Scenario B) showed that scenario A provided a quicker recovery of SSB during the first years of implementation – as expected given that the low level of current SSB (around 110kT) would lead to immediate fishery closure. However over the long-term (average simulation results for the period 2018-2032), no significant difference in the results could be observed between both HCR with regard to average SSB level, risk of SSB falling below 110 kT and average yield. However, scenario B reduced significantly the average inter-annual variability in yield in the long-term.

2.5 Dissemination of results : responses to EC Non paper

PelRAC[2], BSRAC[3] and scientists from DTU Aqua responded independently to the EC Non-Paper, and these contributions provide a view on the understanding and interpretation of the simulation outcomes. All answers referred to and acknowledged explicitly the JAKFISH collaborative process. The target F of 0.25, with 15% limits in TAC variation was agreed by all parts, as well as the 50-50% fixed share between the area IIIa and the area 22-24. The latest ICES assessment estimated F at 0.52 (ICES HAWG, 2010), so both RACs recommendations imply a commitment to stepwise reductions in the TAC in the short-term in order to significantly decrease the fishing mortality and rebuild the stock. Furthermore, PelRAC recommended the establishment of a juvenile target for industrial bycatch (F_{0-1}=0.075)

Of variable interpretation was the transition scheme (reduction in 3 years recommended by PelRAC, reduction in 5 years recommended by BSRAC). Furthermore, the inclusion or exclusion of fleets A and D from the total catch advice to be equally shared was not made fully clear.

3 ADDRESSING NON-QUANTIFIABLE UNCERTAINTY

The uncertainty presented above related to the statistical outcomes of the model. In this case the source of uncertainty is restricted to the data. Since the purpose of our project related to a policy problem, we aimed at defining uncertainty more broadly, including all aspects that might influence the soundness and the relevance of the scientific input to the policy problem. The purpose of addressing other sources of uncertainty was twofold:

- to ensure that the LTMP for the herring stock that the stakeholders (including the scientists) thought was relevant and addressed the right question (*Uncertainty in problem framing*). Fisheries management based on scientific advice started a few decades ago and has been criticised for lack of new ideas and maintaining an advisory framework that is often not suited to the problems (Degnbol et al., 2006, Nilsen and Holm, 2007). Our intention was to make it possible for the stakeholders to reconsider means and measures.

- To communicate non-quantifiable uncertainty in a sufficient way to discuss how or whether uncertainty is accounted for in proposed LTMPs (*Uncertainty in the quality of scientific knowledge*).

Our approach for addressing non-quantifiable uncertainty was driven by the various steps proposed by Walker et al. (2003) and later by Kraak et al.(2010)[4], i.e. i) problem framing by policy makers, stakeholders and analysts, ii) decision support activities, iii)peer reviews, iv) evaluation of outcomes by policy makers and stakeholders – with feedback to i); v) policy decision; vi) implementation and communication, vii) monitoring. This corresponds also to the wider concept of "extended per review" developed by Funtowicz and Ravetz (1993), i.e. the inclusion of stakeholders in the review process in policy questions when science is uncertain, which is by many regarded as necessary to ensure quality (e.g. Funtowicz and Ravetz 1993; Wynne 1992; Funtowicz and Strand 2007; Renn 2007).

[2] http://www.pelagic-rac.org/index.php?option=com_content&view=article&id=136:prac-recommendations-in-2010&catid=24
[3] http://www.bsrac.org/mod_inc/?p=itemModule&id=1319&kind=11&pageId=1533 and also http://www.bsrac.org/mod_inc/?p=itemModule&id=1541&kind=11&pageId=1084
[4] See also JAKFISH deliverables at https://www.surfgroepen.nl/sites/jakfish/Pages/publications.aspx

Uncertainty was discussed throughout the meetings, but was specifically addressed at the main topic in the third meeting. At the early stages of the cooperation, uncertainty was addressed to increase the quality and relevance during the process of proposing and evaluating LTMPs. At the later stage, uncertainty was addressed to review the process (participatory modelling) and the quality and relevance of the final product.

3.1 Problem framing

As described in chapter 2.1, the actual problem addressed shifted from modelling the mixing between both stocks in a bio-economic context to evaluating a proposed Harvest Control Rule suggested by ICES to the EU and proposing preferred alternatives. However, while addressing an important policy issue, it is not certain that the work achieved covered enough of the problem frame. Van der Sluijs et al. (2003), suggested addressing uncertainty in the scientific approach to the policy problem through a questionnaire covering policy objectives and values, policy measures, policy and management problems and the scientific approach.

We did not proceed by questionnaires, but insured that all such issues were raised at the second and third meeting through a round table of questions. However we used a similar questionnaire that was handed out after the final LTMP was decided and evaluated, in order to get feedback on its quality and relevance as part of the extended peer review process. The questionnaire was distributed to all representatives of either the Pelagic RAC or the Baltic RAC. Only three questionnaires were returned.

- The mixing of herring stocks and subsequent consequences for management was again raised at one main issue. The concern was that the existing management principles for the mixed area did not ensure sustainable fisheries. It was decided to try to solve the problem by reducing the scientific uncertainty in the knowledge of the mixing process. The scientists made preliminary analyses of sampling data, which concluded that the natural variability was high and partly unpredictable. Since a substantial part of the uncertainty on the mixing problem still remained, it was decided that this was a management problem that should be resolved in other fora (see chapter 5).

- Another key issue is the general uncertainty and lack of trust in the assessment outcomes, and in particular with regard to juvenile estimates and the over-reliance on scientific surveys in the absence of commercial tuning data. Several of the representatives from the fishermen's organizations claimed that the estimates of juveniles did not coincide with what the fishermen observed. The scientists explained that the most recent juvenile estimates (which are always the most uncertain in traditional catch-at-age analysis) does not play a significant role in the spawning stock biomass and short-term TAC advice. The other major data issue related to commercial tuning data. There was a great desire to cooperate with the scientists to get better sampling of the fisheries data, and the scientists responded quite positively. Not only was this discussed as a way of reducing uncertainty, but it was also thought to increase trust. However, changing time series through cooperation is a question that cannot be resolved through a project like JAKFISH that ends after a few years, but should be resolved through a long-lasting joint effort, such as that already in place for several stocks worldwide.

- The last major uncertainty issue was the lack of stock-recruitment relationship. Besides being a data uncertainty problem, this is also an uncertainty issue linked to defining the LTMP. The ICES framework with its reference points cannot be used. There was a general agreement that this uncertainty problem could be addressed through evaluating a set of harvest control rules by simulation in order to decide on a LTMP robust to this uncertainty.

- Another minor uncertainty issue that was brought up was the effect of cod abundance on natural mortality. There was a general agreement that it has an effect, but the scientists were not able to quantify this.

The simulation model presented in Chapter 2.3 accounted for these particular issues raised, although this technically implied some rough proxies and simplifying assumptions. While better modelling approaches could certainly be developed and additional sources of uncertainty could be accounted for, it is considered that the proposed Harvest Control Rule, implying major reductions in the levels of fishing mortality, should be robust enough to ensure sustainable rebuilding of the stock, provided that it is correctly implemented and adhered to.

3.2 Evaluating and communicating the soundness of scientific knowledge

Funtowicz and Ravetz (1990) recommended the use of "pedigree matrices," or scorecards to communicate the soundness of scientific knowledge. Such matrices have been used several times in science for policy regarding various environmental problems (e.g. Van der Sluijs et al. 2005a; 2005b; Craye et al., 2005). The pedigrees aim at reflecting the quality of data sources, knowledge status, assumptions, types of models used and effectiveness in fisheries management, by giving them a score between 0 (low quality knowledge, expert guess) and 3 (high quality knowledge). Although the scores are quantitative, this is a simple qualitative way to assess the uncertainty and to indicate in a transparent way where there might be a problem. Obviously, elements scoring low should be accounted for more cautiously in the simulations and policy decisions.

The scientists developed such pedigree matrices for the scientific knowledge around WBSS herring (Tables 5 to 7), with the intention to enhance discussions both on the scientific approach and on the policy approach to account for the uncertainty. Each time, the descriptions that match Western Baltic herring are shaded and in italics, and expected better and/or worse knowledge situations that could happen are described in the relevant cases.

The pedigrees for western Baltic herring were divided into three areas of concern. The first (Table 5) aimed at reflecting the status of the knowledge concerning biological parameters and the second (Table 6) on the data. The third was on fisheries related aspects, such as regulations, compliance, bycatch etc. It was not possible to separate fully these categories, for example the quality of the parameter estimation/prediction/function depends not only on understanding why and how they fluctuate, but also on the data quality. The matrices were also explained with accompanying text when submitted to stakeholders.

Those scientists who were introduced to the concept for the first time found it rather intuitive, although there were some minor struggles with defining and scoring the categories. They also found this a useful tool for formalising their knowledge, sharing it within the scientific group to reach internal common understanding as well, and shaping the simulation model accordingly. The reaction by stakeholders to the pedigree matrices depended on their prior level of knowledge. For those most involved in the political process, the pedigrees did not seem to add anything to their knowledge because they were already very familiar with ICES advice and the scientific basis for this particular stock. But when the question was raised as to whether they thought this was useful, one from the fishermen's associations said that "*this would be a very useful tool in standard ICES advice,*" referring to the fact that it would be of help to people less knowledgeable than themselves, and a useful way to communicate uncertainty. However, one of the stakeholders mentioned in the final questionnaires that they still require a lot of explanation to be understood, so it is probably a matter of getting familiar with such a visualization tool.

4 THE ADDED VALUE OF PARTICIPATORY MODELLING

4.1 What would have happened without JAKFISH

It is of course impossible to know with certainty what would have happened without the JAKFISH research project being involved in this question. The JAKFISH project only implied long-lasting financing of the salaries for a number of scientists, but no financial support to any stakeholders, whose participation was managed internally within the RACs. This time availability has been a key positive factor allowing more in-depth consideration of alternative scenarios, evaluation criteria and above all, dialogue and communication. This led to a flexible and responsive bottom-up approach, in contrast to the time-limited top-down procedure of going through an EU special request to ICES.

The first Focus Group meeting in May 2009 revealed great differences in the initial perception of the issues and processes engaged across the various stakeholders present. It is therefore not very likely that a common understanding would have easily emerged in the one-year time frame between the first recommendations by ICES WKMAMPEL (2009) and the publication of the EC Non-Paper. This may have led to misunderstanding and political disagreements between the various stakeholders groups, whilst making it difficult to propose alternatives, which should also have been evaluated.

It is likely that the HCR suggestion coming out of the ICES recommendations, and leading to fishery closure when the stock would be estimated below the 110 000 t threshold, would not have been much adhered to by the stakeholders, with the potential of little commitment to and support for the establishment of such a LTMP and ensuing risk for the recovery of the stock.

It is too early to know the outcomes of Walker et al. (2003) final steps of v) policy decision, vi) implementation and vii) monitoring, as these will judge the final success of the participatory process engaged in JAKFISH. At the time being, we do not yet know if a LTMP will be finally implemented, on which basis (ICES WKMAMPEL recommendations or JAKFISH alternative) and if it will be fully supported by stakeholders.

But we believe that the open and iterative process conducted for the first steps over a long-period of time has created more mutual understanding and collaboration between the various groups, leading to potentially more ownership and support if the alternative HCR is chosen by the EU as the basis for the LTMP.

4.2 What have scientists learned

From the scientists' perspective, engaging in this process was a rich endeavour. The need to address complex quantitative simulations and communicate them to an audience of non scientists, but nevertheless experts in empirical knowledge of the stock being considered was challenging. Stakeholders' commitment to and trust in scientific results requires understanding, transparency and accountability of the modelling choices, and this creates a natural pressure on the scientists to try to produce the best possible science at the time.. As such, the concept of "extended peer-review" performed well, since the scientific work was scrutinised, as is done when being scientifically peer-reviewed for publication. This was certainly beneficial for the quality control of the scientific advice; indeed, some coding errors in the model were spotted on the basis of such results being scrutinised by some stakeholders. However, this also created some discomfort for the scientists when some modelling assumptions are not based on firm science (low score on the pedigree matrices) or are challenged by the stakeholders, especially when the points of non-agreement cannot be resolved. It was very interesting for scientists to consider these points of non-agreement, although including empirical observations and stakeholder knowledge is not a simple task, especially in stock assessment (see also Kraak et al., 2010, Wilson, 2009). Points of non-agreement were mostly dealt with through observation uncertainty in the modelling framework, i.e. uncertainty linked to the scientific observation and stock assessment process, to which more attention was paid than in the case in many published MSE analyses.

An interesting contribution of the participatory modelling was the discussion around evaluation criteria. While scientists usually focus on standard criteria such as probability of SSB falling below a certain threshold, average and inter-annual variability of yield, stakeholders were also interested in more nuanced and detailed results, including average size in the catches (related to price), number of years where the TAC goes up and down respectively, or frequency of the constraint applying on the TAC. Model outputs had thus to be modified accordingly. Finally, the whole iterative process also contributed to improved learning and capacity building around these still relatively new modelling approaches to Management Strategies Evaluations.

Learning from previous experiences in terms of participatory modelling (Van der Sluijs et al. 2005a; 2005b; Craye et al., 2005; Dreyer and Renn, 2010) helped i) to understand the various steps in stakeholders involvement, ii) to formalise the issues and iii) to make use of established tools for evaluating the risks, addressing non-quantifiable uncertainty and communicating all such points. It was interesting to note that the uncertainty pedigree matrices were mostly considered useful by the scientists as a tool to evaluate their own knowledge when producing the matrices, more than by the stakeholders who were already knowledgeable of many of the points raised.

4.3 What have stakeholders learned

From the stakeholders' point of view the project involved a learning process in several ways. First of all, it provided an opportunity to develop an in-depth understanding of the highly complex assessment and management process for WBSS herring, and it not have been possible to achieve this in the usual fora where stakeholders encounter scientists. The setting of having a relatively small group, and the amount of time available to deal with this specific stock, allowed for extensive debate and explanation. Moreover, evaluating the process of collaboration with the scientists helped in understanding how such endeavours should best be organised, and this should for instance benefit the effectiveness of similar processes in the context of the work within the RACs.

Although the project finally focussed more on the options available for HCRs, an understanding was developed of the different aspects of the assessment process and its inherent uncertainties. Despite the fact that this was not followed up on in the course of this project, it was useful to identify the areas where fishermen could potentially contribute to the assessment, possibly by means of setting up a reference fleet or some sort of sampling scheme in order to provide additional information, for instance on recruitment levels or on catch composition in area IIIa. The pedigree matrix provided by the scientists as a tool for regarding the different uncertainties was only discussed briefly, because it confirmed what the stakeholders intuitively already knew from experience, but perhaps also because stakeholders could not relate well to its purpose in the context of the current project. It is likely that it could serve a clearer purpose in a context where improvement of data collection and the assessment is attempted, rather then where management options, based on an accepted assessment framework, are contemplated.

With respect to developing the optimal HCR, the stakeholders were made aware of the time constraints under which ICES had had to deal with the Commission's request to evaluate several options. Very early on in the process it became clear that there was room for manoeuvre outside the one option which ICES had been able to deal with. The group consequently started to explore this space by quantitatively analysing and discussing the trade-offs between different objectives such as yield, risk and stability. This exercise contributed greatly to the stakeholders' understanding of how ICES conducts Management Strategy Evaluations. Perhaps, contrary to expectations, it also became clear that they could play a useful role in this process.

In order to evaluate the stakeholders' opinions on how the participatory modelling process had gone, questionnaires were issued to them, but unfortunately not many were returned. This probably mainly had to do with the fact that for most stakeholders the main purpose of the project was to get results that could be used for a recommendation in response to the Commission's non-paper on a LTM plan, and not to evaluate the participatory modelling process. But they also recognised that they are usually not very fond of such form of communication. Perhaps a shorter questionnaire without open questions would have triggered more responses, or short interviews with individual participants would have worked better. However, the general impression was that the stakeholders appreciated the collaboration that had developed in the project. The openness with which the scientists communicated shortcomings and uncertainties of the assessment perhaps surprised some industry representatives and contributed to establishing a relationship of trust. Although the stakeholders felt that there was an equal working relationship with the scientists, they unfortunately only very late in the process seized the opportunity to make use of this, in terms of taking initiative to prepare and lead a meeting. Perhaps ensuring that stakeholders take up this role earlier in a project like this one would be greatly beneficial in terms of stimulating the dedication and involvement of the stakeholders in the project. It could at the same time be useful, as it would provide the scientists a clear idea about the level of understanding of the stakeholders, which would make it easier to organise the next meetings in a suitable manner.

The effectiveness of the meetings in terms of how much progress was made could have been increased (and thus the number of necessary meetings reduced) if the group had been kept smaller and its composition had been kept more constant on the side of the stakeholders. It was clear that the few meetings where an additional number of people attended who had not been there at the previous meetings inhibited progress, because it resulted in revisiting and explaining some issues that had been discussed earlier. Considering that during the process there were several (political) issues to be discussed and preferences agreed upon among the stakeholders before the collaborative process could continue, it also became clear that it is essential to have involved the relevant industry representatives who have a mandate to make such decisions on behalf of the group of fishermen that they represent. Fortunately, this was true for the majority of the group of stakeholders involved in the current project.

Moreover, in line with consideration about which representatives should be involved in such a project, one may wonder whether the environmental NGO's could have had an active role inside the project from the very start. Although the outcome would probably not have been much different from how it actually turned out, because they were involved in the decision making on the recommendations of the two RACs, it would maybe have made that decision making process easier if they had been involved throughout the project. Similarly, non-EU stakeholders could have been involved since WBSS herring is also caught by Norwegian vessels in area IIIa. This would have been an interesting experiment.

5 FUTURE PERSPECTIVES

5.1 About WBSS herring management

Whatever exact values for (A), (B) and (C) the EU decides to propose and the Council will adopt, very important still is the discussion on the TAC setting procedure for area IIIa alone on the basis of the mixing with NSAS. This was not solved as it was first necessary to agree on the WBSS single-stock management objectives, but is the next step in the procedure. An ICES workshop on this topic has been scheduled for the end of November 2010, gathering some of the JAKFISH scientists, but also scientists from other countries bordering area IIIa. This workshop, which will be open to stakeholder participation, will aim at 1) quantifying the fixed and variable patterns in the degree of mixing between both stocks and 2) developing integrated and robust forecast procedures accounting for both stocks together and based on the single-stock LTMP objectives already implemented for NSAS herring and coming out of the work presented above for WBSS herring.

Besides, initial objectives to improve stock assessment and recruitment estimates in general are still very valid. In the earliest stage of the JAKFISH project, the possible setting up of a reference fleet in order to improve data collection was touched upon. There was considerable enthusiasm with some of the stakeholders to realise this. This should be a priority in future endeavours relating this stock.

5.2 About participatory modelling and Results-Based Management

In this process engaging stakeholders and scientists around complex policy and governance issues, we placed uncertainty at the heart of the discussions. We found ourselves exactly in the situation referred to as "*Post-Normal Science*" by Funtowicz and Ravetz (1993), i.e. that the science needed for policy when uncertainty is large and stakes are high is no longer purely academic "*normal*" science, but applied, problem-solving science. While this has long been recognized in other fields of natural resource hmanagement, the uptake of this concept has emerged only recently in fisheries science, together with the increased development of long-term management plans. And this shift in the role of science has raised major questions in the scientific community (see e.g. Rochet and Rice 2009, Butterworth et al. 2009, Kraak et al., 2010, Wilson, 2009).

Involving stakeholders in an “extended peer review” process has acted as a natural and positive driving force for changing the whole perspective in fisheries management, from top-down short-term advice to bottom-up long-term commitment. The need to justify and explain the reasoning behind the scientific models, the outcomes of which will directly impact the livelihood of the stakeholders involved, leads to an auto-evaluation of the quality and soundness of the scientific knowledge (illustrated by the pedigree matrices), which in turns focuses the attention towards the most uncertain but important factors. This drives a natural and shared understanding that these factors should then be accounted for in the models, but with large confidence intervals around parameter values and related natural processes, and that the policy decisions should account for the potential risks linked to them. And if scientific uncertainty cannot be resolved, then the management must adapt to it and be precautionary. In some simulations being run with the same underlying dynamic of the herring stock, but with assumed perfect levels of knowledge, the uncertainty in management outcomes was considerably reduced, and higher yields were allowed. The participatory modelling process makes it easier to understand this fact, and for it to then be accepted.

A direct consequence of this is that it is in the interest of the stakeholders to actively participate in the reduction of scientific uncertainty, as this would lead to improved management and thereby greater fishing rights. This approach is the key idea behind the results-based management and the reversal of the burden of proof, and we have experienced directly in our case study that such participatory modelling was an integrated part in shifting to this paradigm.

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	Western Baltic herring (*)	Central Baltic herring	Gulf of Riga herring		Sprat
Fishing mortality **[A]** (year^{-1})	< 0.25	0.22	0.26	0.35	0.40
Annual TAC variation **[B]** (± percentage)	15	15	15	20	20
Spawning-stock biomass **trigger** **[C]** ('000 t)	None	800	60		400
Probability of SSB_{2015}<**[C]**	< 5% (**)	< 5%	< 5%		< 5%
B_{lim} ('000 t)	110 (***)	385	40		200
When SSB<B_{lim}	F = 0	F = 0	F = 0		F = 0
F when B_{lim}<SSB_y<[C]	Not Applicable	$0.22*[(SSB_y-385)/(800–385)]$	$0.26*[(SSB_y-40)/(60–40)]$	$0.35*[(SSB_y-40)/(60–40)]$	$0.40*[(SSB_y-200)/(400–200)]$
Spawning-stock biomass in 2015 SSB_{2015} ('000 t)	(*)	1 056	117	101	962
Yield in 2015 Y_{2015} ('000 t)	(*)	190	24	29	256

Table 1 – ICES WKMAMPEL (2009) recommendations for the establishment of multi-annual management plan for the pelagic stocks in the Baltic.

Long-Term	Refers here to the period 2018-2032, i.e a 15 years average after that the HCR has been implemented on a full lifespan of a cohort (8 years) and the stock has stabilized
Btrigger (kT)	Biomass trigger point which indicates a change in action
LTavgYield (kT)	Mean annual catch over the long-term
LTavgF	Mean realized F over the long-term
JuvRatio	Ratio of juveniles (ages 0 and 1) in total catches in weight
MeanIAV (%)	Mean absolute variation in the TAC between years
NupTAC	Total number of times that the TAC was adjusted upwards
NdownTAC	Total number of times that the TAC was adjusted downwards
NupIAV	Total number of times that the IAV rule came into action, preventing TAC increase bigger than 15%
NdownIAV	Total number of times that the IAV rule came into action, preventing TAC decrease bigger than 15%
TAC up (t)	Mean amount of increase when the TAC goes up
TAC down (t)	Mean amount of decrease when the TAC goes down
P(<Blim09-12)	Probability of SSB falling below 110 kT between 2009 and 2012
LTavgSSB	Mean spawning stock size over the long-term
SSB2032	Stock size at the end of the simulations
MeanAge	Mean age of the population in numbers
<Blim1Yr	Proportion of runs where SSB was below 110kT at least once over the long-term
<Blim2Yr	Proportion of runs where SSB was below 110kT at least twice over the long-term
P(<Blim)	Probability of SSB falling below 110 kT over the long-term
HC	Human Consumption (ages 2-8)

Table 2 – Evaluation criteria

HCR				Stock in 2012		Stock results 2018-2032						Error check
nr	target	targ_value	Btrigger	SSB2012	P(<Blim09-12)	LTavgSSB	SSB2032	MeanAge	<Blim1Yr	<Blim2Yr	*P(<Blim)*	failing iters
1	f	0.25	NA	120	20.4	197	195	1.78	8.1	4.9	*1.1*	0
2	f	0.25	80	120	20.4	197	195	1.78	8.1	4.9	*1.1*	0
3	f	0.25	110	120	20.4	198	195	1.79	7.9	4.7	*1.1*	0
4	f	0.25	150	122	19.8	205	197	1.82	6.3	4.1	*0.9*	0
13	f	0.26	114.4	119	21.9	192	188	1.76	12.7	8.3	*1.9*	0
14	f	0.27	118.8	118	23.2	187	182	1.73	17	12.1	*2.9*	1
15	f	0.28	123.2	116	24.6	182	176	1.71	22.3	16.3	*4*	1
16	f	0.29	127.6	115	25.8	176	171	1.69	29	20.8	*5.5*	2
17	f	0.3	132	114	27	173	167	1.68	37.5	27.2	*7.3*	16

	Fishery in 2012		Average Fishery 2018-2032			Inter Annual Variability in Yield 2018-2032						
nr	Yield2012	F2012	LTavgYield	LTavgF	JuvRatio	MeanIAV	NupTAC	NdownTAC	NupIAV	NdownIAV	TAC up (t)	TAC down(t)
1	39	0.23	59	0.25	0.14	11.58	9	7	5	4	6140	-6423
2	39	0.23	59	0.25	0.14	11.58	9	7	5	4	6140	-6439
3	39	0.23	59	0.25	0.14	11.67	9	7	5	4	6152	-6507
4	35	0.2	59	0.24	0.13	12.02	9	7	6	4	6239	-6645
13	39	0.23	60	0.26	0.14	11.76	9	7	5	4	6221	-6651
14	40	0.24	60	0.27	0.14	11.88	9	7	5	4	6301	-6722
15	40	0.24	61	0.27	0.15	12.04	9	7	6	4	6420	-6802
16	40	0.25	61	0.28	0.15	12.18	9	7	6	4	6485	-6953
17	41	0.25	61	0.29	0.15	12.38	9	7	6	4	6594	-7032

Table 3 Main results for HCR 1-4 and 13-17 with 1000 iterations and ICES ICA assessment results. Lines shaded in red are those where P(SSB<Blim) over the period 2018-2032 (the column in italic) is larger than 5%.

HCR					Stock in 2012		Stock results 2018-2032				Fishery in 2012		Average Fishery 2018-2032		
nr	target	targF3-6	Btrigger	targF0-1	SSB2012	<Blim09-12)	LTavgSSB	SSB2032	MeanAge	*P(<Blim)*	HC 2012	F3-6 2012	HC yield	F 3-6	Juv Yield
3	f	0.25	110	NA	118	21	197	191	1.77	*0.8*	31	0.23	51.3	0.25	8
3	f	0.25	110	0.05	119	20.5	212	198	1.83	*0.3*	30.9	0.22	53.5	0.24	5.5
3	f	0.25	110	0.06	118	23	209	195	1.82	*0.4*	30.6	0.22	52.4	0.24	6.5
3	f	0.25	110	0.07	117	23	205	192	1.81	*0.4*	30.3	0.22	51.2	0.24	7.5
3	f	0.25	110	0.08	117	23.5	203	189	1.8	*0.9*	30	0.22	50.2	0.24	8.5
3	f	0.25	110	0.09	116	24.5	201	185	1.8	*1*	29.6	0.22	49.1	0.24	9.5
3	f	0.25	110	0.1	115	25.2	199	182	1.79	*1.2*	29.3	0.22	48	0.24	10.5
15	f	0.28	123.2	NA	115	26	180	171	1.69	*2.7*	32	0.24	52.2	0.27	8.7
15	f	0.28	123.2	0.05	115	25.5	196	183	1.77	*1.1*	31	0.23	55.1	0.27	5.5
15	f	0.28	123.2	0.06	114	26.8	193	179	1.76	*1.4*	30.8	0.24	54	0.27	6.5
15	f	0.28	123.2	0.07	113	27.5	191	177	1.76	*1.9*	30.5	0.24	52.7	0.27	7.5
15	f	0.28	123.2	0.08	112	28.2	191	174	1.74	*2.2*	30.3	0.24	51.4	0.26	8.5
15	f	0.28	123.2	0.09	111	29	190	171	1.74	*2.9*	30.2	0.24	50.3	0.26	9.4
15	f	0.28	123.2	0.1	110	30	188	167	1.73	*3.6*	30.2	0.23	49	0.26	10.4

Table 4 : Comparison of HCR 3 and 15 (100 iterations) without additional juvenile target F (age 0-1) and with implementing a constant juvenile target F between 0.05 and 0.1.

nr	Shape	SSB 2012	LT SSB	*LT P(SSB<Blim)*	Yield 2012	LT Yield	LT TAC up	LT TAC down
A	"stepwise"	137	195	*0.7%*	36	59	11.1	-10.6
B	"sloped"	121	198	*1.1%*	39	59	6.1	-6.5

Table 5. Comparison of HCR scenarios for WBSS Herring. Scenario A : Scenario as suggested in the non-paper. Scenario B : scenario considered during the JAKFISH project. LT = Long-Term average (2018-2032). TAC up /down : Mean amount of annual increase / decrease when the TAC goes up / down. Results expressed in kTonnes.

	Stock - recruitment	*Growth*	*Natural mortality (M)*	*State of stock (input in LTMP simulations)*	*Impact of climate change*
4	Clear visual and functional relationship	Well sampled and causes of fluctuations are well understood	Reliable estimates of M	*High quality assessment with uncertainty estimates*	Well understood consequences of experienced temperature fluctuations
3	Possible relationship	*Well sampled, but causes of fluctuations poorly understood*	Reliable estimates of M, but not at early life stages	High quality assessment, but limited focus on uncertainty estimates	Known impact on growth or recruitment or distribution
2	*No clear relationship, recent average used*	Poor sampling, and environmental effects on growth poorly understood	Poor estimates of M.	Rather low quality assessment	*Limited knowledge, and not accounted for in modelling*
1	Unknown	Unknown	*Unknown predation by cod and other top predators of the ecosystem*	Inadequate data and knowledge in assessment	No knowledge of temperature effects on stock

Table 6. Pedigree matrix 1. Knowledge status of key biological parameters. The WB herring score for each parameter is highlighted in italics and shades.

	Survey	*Recruitment observations*	*Catch data*
4	*Good coverage and good sampling scheme*	Good survey coverage. In agreement with fishermen	Full compliance and sufficient sampling schemes.
3	Partly covered	Partly covered by survey, but the picture coincides largely with fishermen's observations	*Compliance estimates included, and sampling schemes with some good coverage but some gaps as well*
2	Ad hoc coverage in time or space	*Partly covered but disagreement between scientists and fishermen about status*	Compliance problems or serious sampling problems
1	No	No data	Quality unknown

Table 7. Pedigree matrix 2. Data quality

	Selectivity by fleet	*Stock interactions, same species*	*Management of spatial components*	*Bycatch in other fisheries*	*Implementation*
4	Fairly well sampled. Predictable due to stable fleet and gear situation	No mixing, not a problem	Fully accounted for	Very low bycatch	Advice followed and adequate catch control
3	*Fairly well sampled, but not predictable*	*Mixing occurs but is sampled and monitored*	*Partly accounted through spatial and fleet-based data*	*All Bycatch counted against the quota*	*Advice usually followed. Control increases compliance*
2	Poorly sampled and not predictable	Mixing and not addressed adequately	Not accounted for. Limited knowledge on how to separate components.	Some technical regulations, but a problem	Limited control
1	Not handled	Unknown and not addressed	Unknown whether separate components exist.	Unkown, not addressed	Advice not followed and limited control

Table 8. Pedigree matrix 3. *Management and fisheries specific issues that can affect the quality/relevance of a LTMP*

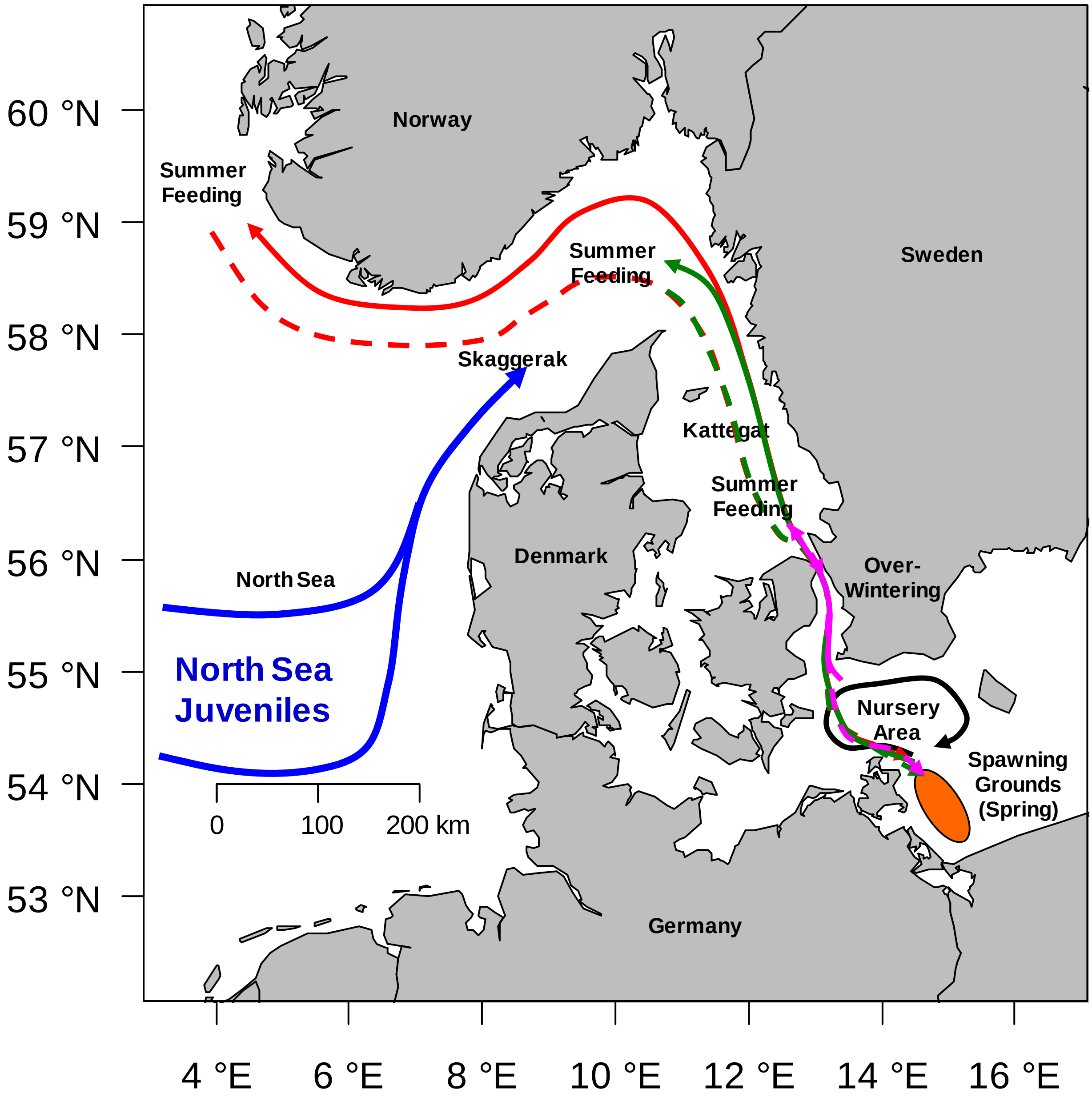

Figure 1 – Empirical knowledge on herring migrations.

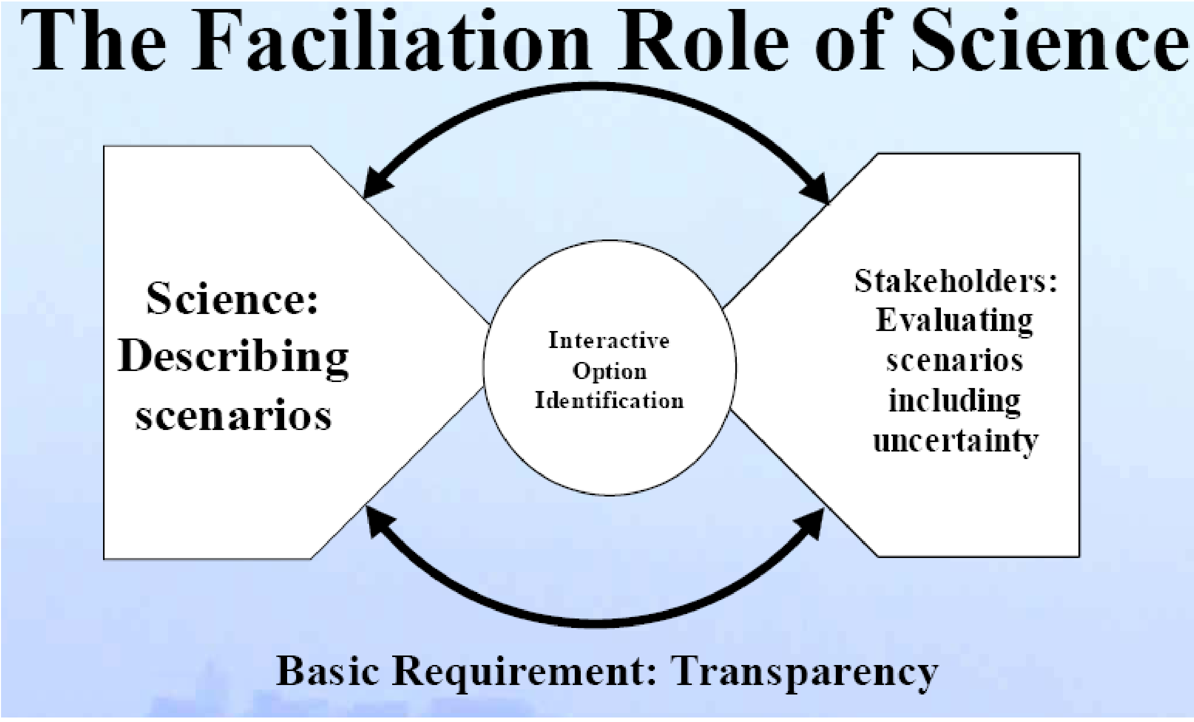

Figure 2. The concept of participatory modelling

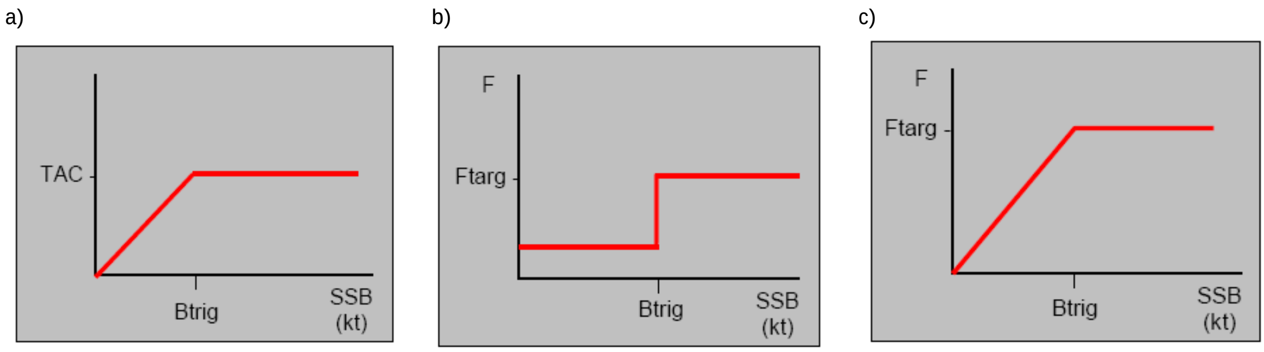

Figure 3 – Various HCR shapes tested. a) : Constant TAC rule, b) : Target F stepwise approach, c) : Target F sloped approach.

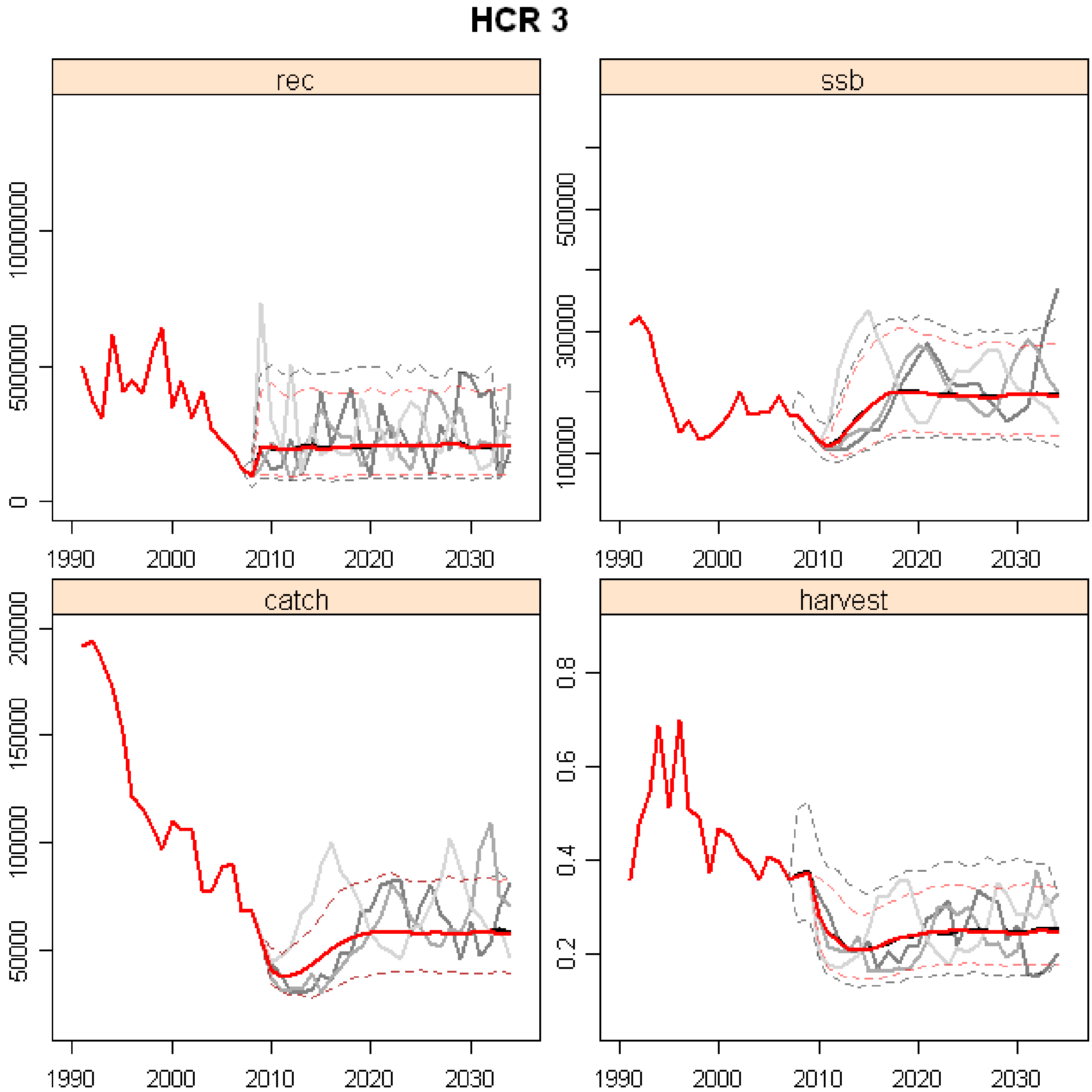

Figure 4 : Median trajectories (bold) and 5-95% confidence intervals (dotted line) for 1000 iterations with the HCR 3 (target F=0.25 and Btrigger=110 kT) for the simulated stock (in red), the results of the stock assessment (black), as well as the individual trajectories of the first 3 iterations in grey, illustrating the variability of each individual realization. Rec=Recruitment at age 0, harvest= mean F on ages 3-6.

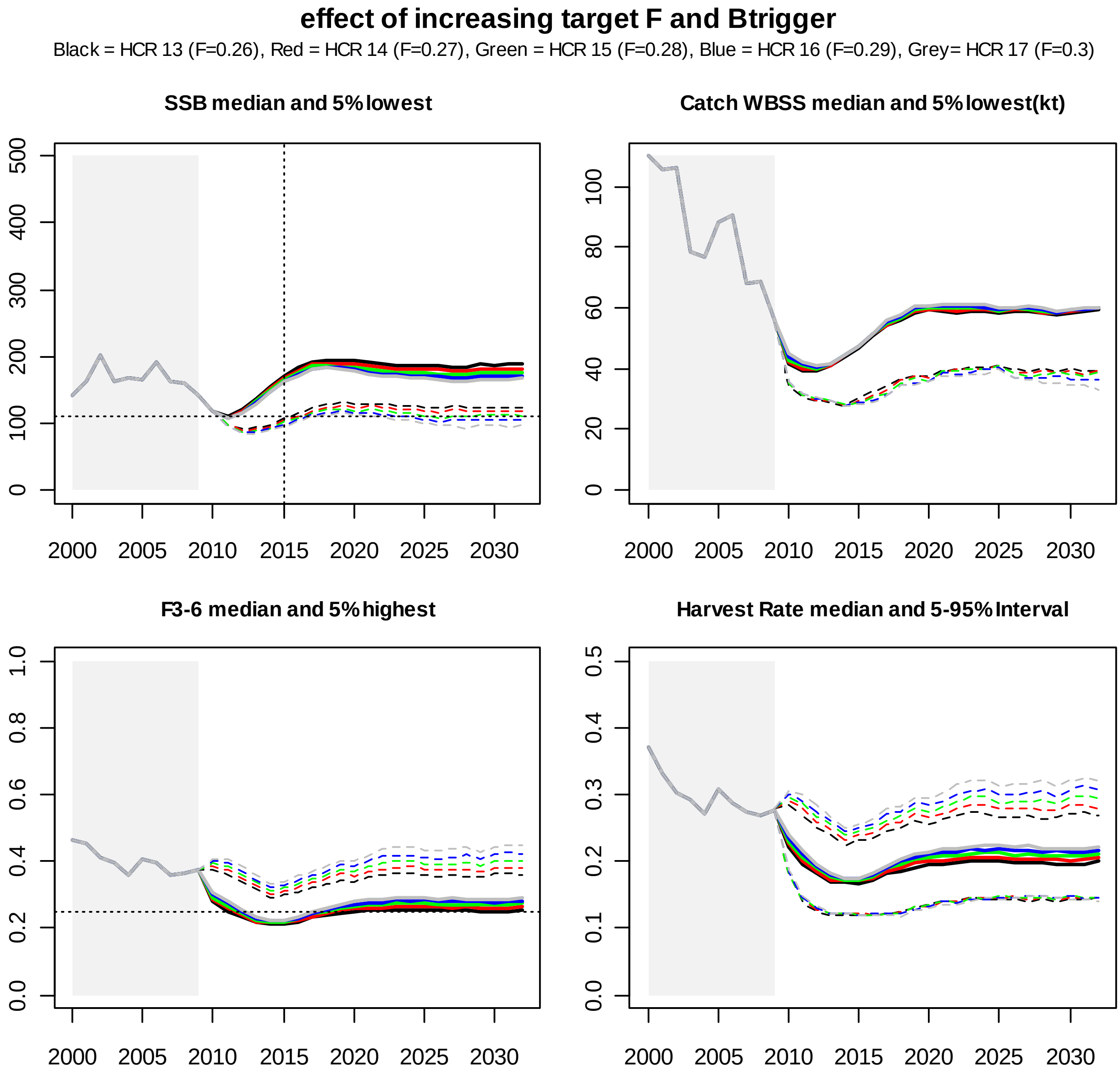

Figure 5. Median bold and 5% "worst case" results, HCR 13-17

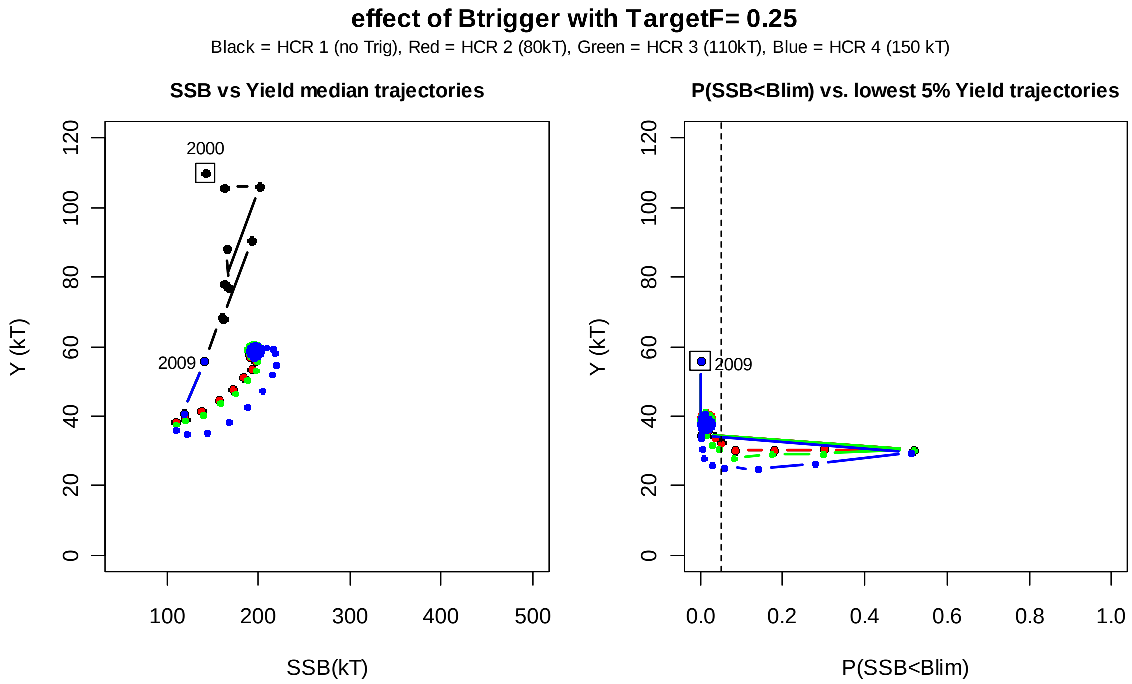

Figure 6. Left plot: Tradeoff trajectories showing median SSB vs. median yield by year. Right plot : Risk plot showing the probability of SSB falling below 110 000 tonnes, vs. the lowest 5% of the yield values by year. Starting values are shown with a square, and end value (2032) are shown with a large dot.